

# A COMPARISON OF THE HIGHEST PRECISION COMMONLY AVAILABLE TIME TRANSFER METHODS: TWSTT AND GPS CV

James A. DeYoung, Francine Vannicola, and Angela D. McKinley  
U.S. Naval Observatory, Time Service Department  
3450 Massachusetts Avenue NW, Washington, DC 20392, USA  
dey@herschel.usno.navy.mil, fmv@cassini.usno.navy.mil, amd@tycho.usno.navy.mil

## Abstract

*The U.S. Naval Observatory (USNO) in Washington, D.C., is now operating its Alternate Master Clock (AMC), located at Falcon Air Force Base, Colorado. UTC(USNO)-UTC(AMC) is determined independently by the Global Positioning System (GPS) common view (CV) and the Two-Way Satellite Time Transfer (TWSTT) method. The GPS CV time transfer data are formed from strict 13-minute common-view tracks. The TWSTT data are single 5-minute runs taken once every hour. In this study, the performances of the GPS CV time transfers from Standard Positioning Service (SPS) C/A code single-channel receivers using the modeled ionosphere, Precise Positioning Service (PPS) dual-frequency receivers using the measured ionosphere, and TWSTT are compared.*

## ACKNOWLEDGMENTS

We thank the USNO Time Service Department, Washington, D.C., employees involved in TWSTT and GPS; Dr. G.M.R. Winkler and Dr. W.J. Klepczynski, formerly of USNO, for making the investment in TWSTT hardware at USNO over the years, and Bill Bollwerk and Steven Hutsell of the USNO AMC at Falcon AFB, Colorado.

## Introduction to the Topic...

GPS Common-View (GPS CV) and Two-Way Satellite Time Transfer (TWSTT) are being performed between USNO, Washington, DC and the USNO Alternate Master Clock (AMC), Falcon AFB, CO.

This paper will show the results of a comparison of the two time transfer methods for UTC(USNO(MC2))-UTC(USNO AMC (MC1)).

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>DEC 1996</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-1996 to 00-00-1996</b>	
4. TITLE AND SUBTITLE <b>A Comparison of the Highest Precision Commonly Available Time transfer Methods: TWSTT and GPS CV</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>U.S. Naval Observatory, Time Service Department, 3450 Massachusetts Ave NW, Washington, DC, 20392</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADA419480. 28th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, Reston, VA, 3-5 Dec 1996</b>					
14. ABSTRACT <b>see report</b>					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>7</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## **GPS Hardware**

- Stanford Telecom (STel) Time Transfer System (TTS) Model 5401C
- Single-channel receiver, dual-frequency, P-code/Y-code (i.e. authorized, correcting for selective availability and anti-spoof)
- Ionosphere measured
- Antenna coordinates good to  $< 1$  meter

### **GPS receiver tracking schedules are optimized to...**

- maximize the number of usable common-view passes
- have balanced use of all satellites
- have a track at the beginning, middle, and end of a pass
- have none tracked below 20 degree elevation

*45 degree limit used for this paper resulted in a usable CV about every hour which is comparable to the TWSTT sampling rate.*

## **TWSTT Hardware**

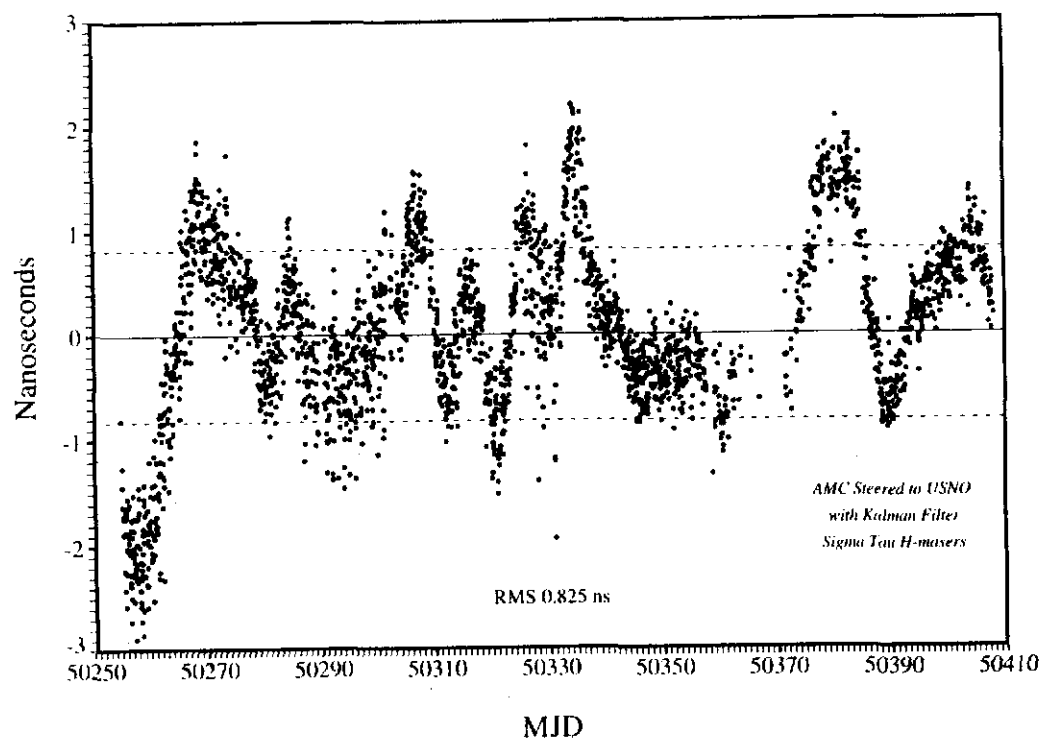
- Allen Osborne Associates, Inc. TWT-100 "Atlantis" Modem
- PRN-coded (2.5 MHz), Spread-Spectrum, bi-phase-modulated, 70 MHz IF, Ku-band RF transmissions
- All known delays accounted for, Total delays measured by portable VSAT and confirmed with portable clock comparison
- Baseline distance is 1475 miles (2374 km)
- Commercial geostationary Ku-band satellites at 103.1 degrees West, GSTAR-1 and follow-on GE-1 were used

## **IMPORTANT TWSTT DETAILS**

- Sampling rate is @1 hour (a 5 minute long (300 second) set of 1pps comparisons then an average taken)
- Prototype software package (C and Linux-bugs still exist) is used to allow automation of
  - ◆ modem control
  - ◆ data collection and scheduling
  - ◆ error handling and resolution
  - ◆ data preparation and transfer
- Final data used by Kalman filter for subsequent steering of the USNO AMC Hydrogen maser synthesizer at USNO AMC

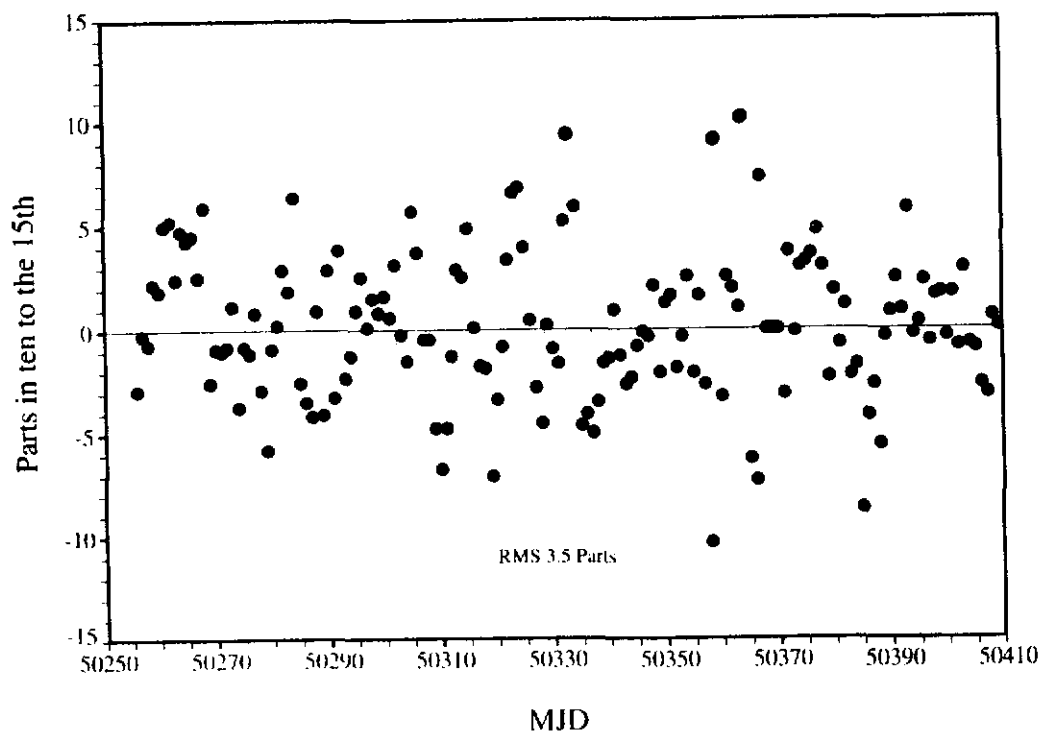
UTC(USNO(MC2)) - UTC(USNO AMC(MC1))

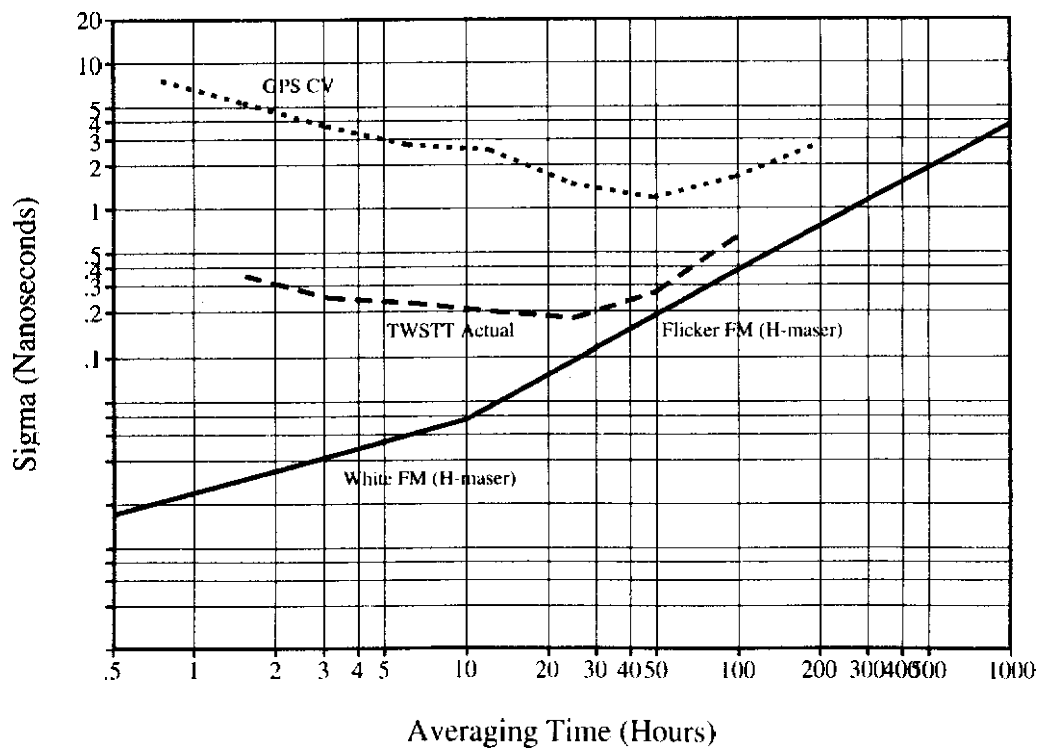
via TWSTT



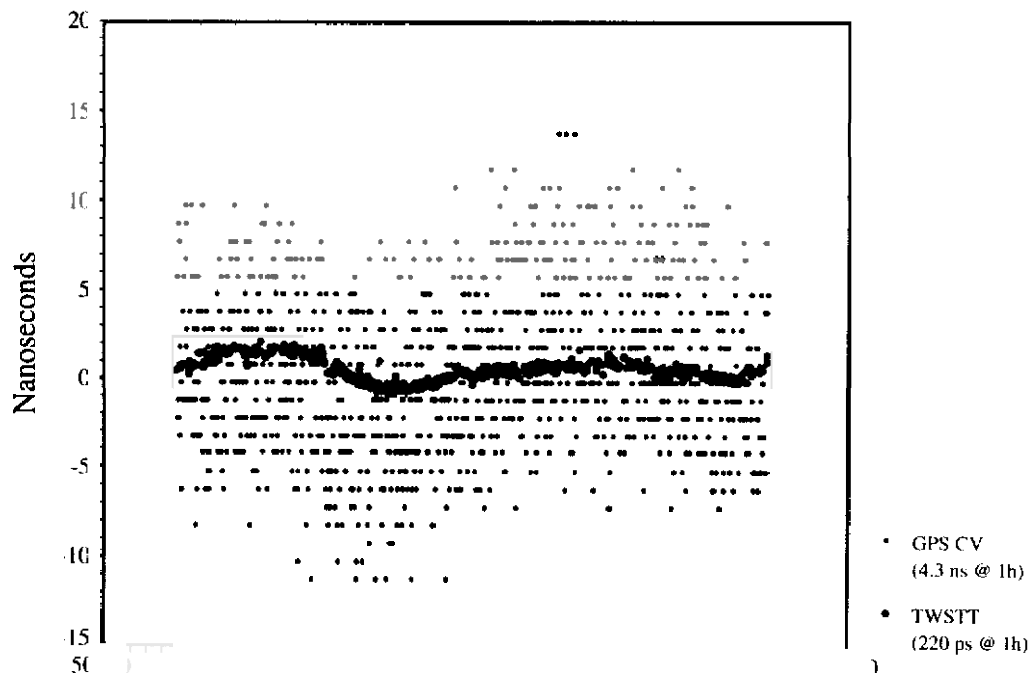
UTC(USNO(MC2)) - UTC(USNO AMC(MC1))

Daily Frequency Offsets



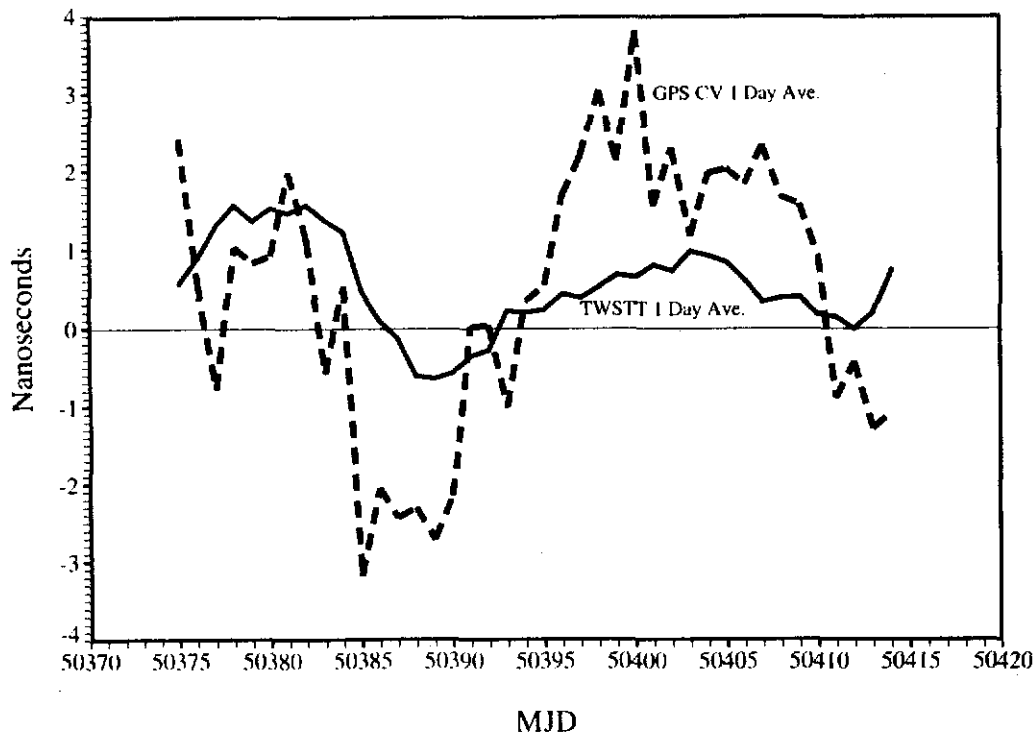


UTC(USNO(MC2)) - UTC(USNO AMC(MC1))  
via GPS CV and TWSTT (Sampling Rate @ ~1h)



UTC(USNO(MC2)) - UTC(USNO AMC(MC1))

via GPS CV and TWSTT (1d simple Means)



### IMPORTANT RESULTS FROM THIS WORK

- Near-optimal sampling rates achieved in TWSTT and shows clearly TWSTT is useful for comparing and/or steering the best clocks over long distances.
- Realized Time-Domain performance (RMS) of 800 picoseconds over 160 days
- Realized Frequency-Domain performance (RMS) of 3.8 parts in ten to the 15th over 160 days
- One-day simple averages formed from GPS CVs show systematics at the 3 to 4 nanosecond level with respect to TWSTT!
- "Learning experiences"

## Questions and Answers

DAVID STOWERS (JPL): I have kind of a tangential question asking why would you have selected LINUX as the control software operating system?

JAMES DeYOUNG: From my point of view, I'm a UNIX person. Ultimately, I think the decision was that the prototype software that we're using is under development by NRL, and the path of least resistance ultimately was to use their software. You have to remember that the Alternate Master Clock came up very quickly. The hardware was installed in an extremely short amount of time, so very little software work had been done in preparation because all of this stuff happened within the space of basically a year. So we had to get something together very, very quickly.

Ultimately, I think, LINUX, the UNIX script language with which I'm most familiar, made it very easy to do all of the error control, talk to the interface and see which is a socket server and all of these things. And it's a beautiful way to actually control hardware and those sorts of things. I mean, ultimately I think it's the way to go. To do this in DOS or some other method would be extremely difficult, if not impossible.

DAVID STOWERS: I guess the question I should have asked was versus a commercial UNIX operating system.

JAMES DeYOUNG: Well, seeing that we have had some firmware problems, at least at that level, LINUX may not be the way to go, and that's going to be investigated down the road, because we do have to improve the reliability of the time transfers. Anywhere from 70 to 90 percent are done per day in two-way automatically and we need to get that basically to a hundred.